Click here to return to main document and Bookmarks

Other PAHs were detected in SS-08, SS-22, and SS-23 at concentrations ranging from 23 to 120 µg/kg. Two pesticides, 4,4'-DDT (0.38 to 5.2 µg/kg) and 4,4'-DDE (0.38 to 11 µg/kg), were found in SS-07, SS-18, SS-22, and SS-23. Endrin ketone was found at a concentration of 2.3 µg/kg in SS-08. These pesticides were also found in background surface soil, although at lower concentrations. PCBs were not detected in any of the samples. SS-22 and SS-23 are located downslope and downgradient of the Bulky Waste Area, near large leachate outbreaks. SS-18 is located downslope of the Solid Waste Area, and SS-08 is located on residential property.

Major-metal ions (aluminum, iron, calcium, magnesium, and potassium), barium (3.1 to 3.5 mg/kg), lead (2.8 to 6.3 mg/kg) manganese (12.9 to 6,120 mg/kg), vanadium (3.2 to 27.2 mg/kg), and zinc (10.3 to 37.4 mg/kg) were detected in each of the samples. Other metals detected include beryllium (0.37 to 0.88 mg/kg), arsenic (3.1 to 3.5 mg/kg), chromium (3.2 to 13.9 mg/kg), cobalt (3.8 to 12.8 mg/kg), copper (2.8 to 6.3 mg/kg), mercury (0.2 to 4.1 mg/kg), nickel (6.2 to 10 mg/kg), and selenium (5.9 mg/kg). Concentrations of major-metal ions were larger than those of the other metals detected: aluminum was 1,740 to 14,400 mg/kg, iron was 4,090 to 149,000 mg/kg, and basic cations were 106 to 1,710 mg/kg. The number of metals as well as concentrations tended to be higher in surface soil collected near leachate seeps (SS-18, SS-22, and SS-23). In particular, iron concentrations (15,100 to 149,000 mg/kg) at these locations were elevated in relation to background surface soil. Elevated iron concentrations were also found at SS-21 (40,500 mg/kg), collected from a large area of orange-stained soil to the east of the Solid Waste Area, presumed to be a dried-up leachate seep or drainage area.

Cyanide was not detected in any of the surface soil samples. The organic content of soils analyzed for TCO ranged from 3.2 to 12.6%.

Subsurface Soils Results Summary. Within the disposal areas, seven soil boring locations, including one background, four located in the Sewage Sludge Area, and one each in the Bulky and Solid Waste Areas, were drilled to collect subsurface soils. Fourteen samples were collected from the seven borings (two from each boring). The chemicals detected included typical municipal and industrial wastes: ketones, toluene, PAHs, phthalates, phenols, pesticides, and dichlorobenzenes. These compounds were similar to the types of compounds detected in surface soils and landfill gas. Although several metals were detected, most were not significantly elevated compared to background soils. Buried waste provides an active source for the release of contaminants to subsurface soils.

Background Results. The background boring, BH-05, was located in a wooded area just northwest of the Sewage Sludge Area. Trees in the area appear to be at least 20 to 30 years old. In addition, aerial photographs taken from 1941 to 1988 (United States Environmental Protection Agency1987a, 1991a) indicate that excavation has not occurred and that this location has remained largely undisturbed during landfill operations. Glacial outwash was present throughout the boring. For these reasons, the samples collected from BH-05 are considered to be representative of background conditions in subsurface soils.

Volatile organics, pesticides, and PCBs were not identified in either of the samples from BH-05. The only semivolatile organics detected in samples from this boring were two phthalates, at concentrations less than sample quantitation limits. Di-n-butylphthalate was detected at 62 µg/kg from 0 to 2 feet, and di-n-octylphthalate was detected at 19 µg/kg from 10 to 16 feet but was not detected in the field duplicate for this sample.

Major-metal ions (aluminum, iron, magnesium, and potassium) were detected in both samples at concentrations that were higher than those for other metals. Concentrations ranged from 3,955 to 11,800 mg/kg for aluminum, from 6,415 to 12,800 mg/kg for iron, and from 415 to 1,350 mg/kg for magnesium and potassium. Calcium and sodium were also detected, but were not reported because of qualifications during validation. Beryllium (0.47 to 0.59 mg/kg) and seven heavy metals including chromium (3.8 to 9.2 mg/kg), cobalt (3.1 to 5.4 mg/kg), copper (3.4 to 3.5 mg/kg), lead (2.6 to 12.6 mg/kg), manganese (125 to 148 mg/kg), vanadium (6.2 to 19.3 mg/kg), and zinc (12.1 to 20 mg/kg) were also detected in each of the samples. In addition, barium (19.1 mg/kg) and mercury (0.15 mg/kg) were each detected in only one sample. All of these metals were also detected in background surface soils. With the exception of beryllium and cobalt, which were as much as two times greater, concentrations of the metals detected were within the range found in background surface soil. Aluminum concentrations were higher than those reported for soils in the eastern United States, but were lower than those reported for Rhode Island (Table 7).

Cyanide was not detected in either of the background subsurface soils. An organic content of 0.7% was measured in BH-01 (10 to 16 feet). The grain-size distribution shows that the outwash material is predominately composed of sand (51.1%), with some silt and small quantities of clay and gravel present (39.4, 3.1, and 6.5%, respectively).

Sewage Sludge Area Results. Four borings (BH-01 to BH-04) were advanced in the Sewage Sludge Area. Soil borings BH-01, BH-03, and BH-04 were located to evaluate minor landfill gas readings, while BH-02 was advanced to help define the western perimeter of the disposal area boundary. Between 2 and 6 feet of topsoil and fill material were encountered at the top of each borehole. At BH-02 and BH-04, the remainder of the borehole consisted of glacial outwash material. Although no odors, staining, or sludge material were observed in these borings, organic vapors were measured in BH-04. Sludge material and sewage odors were evident during advancement at BH-01 and BH-03. Elevated organic vapor levels were also measured in these borings.

The analytes detected are summarized in Table 6. The organic compounds detected are shown on Figure 8. Volatile organics, phenols, phthalates, and pesticides were detected in several subsurface soil samples. PCBs were not found in any of the samples.

No volatile organics were detected in the shallow sample at BH-03 (2 to 4 feet) or in either of the samples collected at BH-02 and BH-04. Sludge material and sewage odors were observed in the samples in which volatile organics were found. Toluene was detected in one sample, BH-03 (16 to 20 feet). Acetone and MEK were each found in samples from BH-01 (2 to 8 feet and 10 to 16 feet) and in BH-03 (16 to 20 feet). Concentrations ranged from 84 to 740 µg/kg for acetone and 73 to 340 µg/kg for MEK. Acetone was also found in landfill gas at a depth of 12 feet in this area (section 4.2.8). The highest concentrations for both these chemicals occurred in BH-01 (2 to 8 feet).

Phenol, PAHs, and phthalates were found in BH-01, BH-02, and BH-03. One PAH, 2-methylnaphthalene was detected at 27 and 140 µg/kg in the two samples from BH-01 (0 to 8 feet and 8 to 10 feet, respectively). Likewise, 4-methylphenol (2,200 and 5,600 µg/kg) was found in the two samples from BH-01 (2 to 8 feet and 8 to 10 feet), respectively. Phenol (240 µg/kg) was also detected in the shallow sample (2 to 8 feet). Concentrations of these compounds tended to be higher in the sample from 2 to 8 feet than in the deeper sample from 8 to 10 feet. Another phenol, 2-methylphenol (700 µg/kg), was detected from 16 to 20 feet at BH-03.

Phthalates, which are ubiquitous in the environment, were found in all of the borings in this area and in background subsurface soil. Two phthalates were detected at concentrations less than the sample quantitation limit. Di-n-butylphthalate was detected at concentrations ranging from 40 to 120 µg/kg in four samples: BH-02 (8 to 10 and 16 to 18 feet), BH-03 (16 to 20 feet), and BH-04 (8 to 10 feet). Di-n-octylphthalate was detected in BH-02 (16 to 18 feet) and BH-03 (16 to 20 feet) at concentrations of 26 to 86 µg/kg, respectively. Although BH-02 and BH-04 were composed of glacial outwash, it is likely that the material was disturbed because of the extensive excavation throughout the disposal area.

Two chlordane pesticides (*alpha* at 6.2 mg/kg and *gamma* at 7.5 mg/kg) were detected in one sample, BH-01 (2 to 8 feet). *alpha*-Chlordane was also detected in surface soil and is typically found in Sewage Sludge Landfills.

Of the 15 metals detected in the subsurface soils in this area, major-metal ions (aluminum, iron, magnesium, and potassium) were detected at the highest concentrations (367 to 8,635 mg/kg). Aluminum concentrations ranged from 3,705 to 6,000 mg/kg, iron ranged from 3,400 to 8,635 mg/kg, and magnesium and potassium ranged from 367 to 1,700 mg/kg. Beryllium (0.35 to 0.71 mg/kg) and six heavy metals, including chromium (1.6 to 8.9 mg/kg), cobalt (1 to 6.3 mg/kg), copper (4.2 to 79.2 mg/kg), lead (2.3 to 8.8 mg/kg), vanadium (5.7 to 11.4 mg/kg), and zinc (16.5 to 188 mg/kg), were reported in at least seven of the samples (Table 4-8). Barium (10.1 to 54.3 mg/kg), antimony (5.4 to 16.8 mg/kg), manganese (106 to 213 mg/kg), and mercury (0.13 to 0.47 mg/kg) were detected less often.

Generally, the highest concentrations were found in one of the two samples from BH-01. Except for antimony, all of the metals detected were also found in background surface soils. Most of the metal concentrations were near (less than two times greater) or within the range detected in background subsurface soils. Barium and manganese were as much as two to three times higher, while zinc was as much as nine times higher, and copper was as much as 20 times higher than the concentration detected in background surface soil.

As shown in Table 8, elevated metal concentrations typically occur in sewage sludge landfills. The highest metal concentrations tended to occur in samples collected from BH-01 and BH-03, where sludge was observed. Even though large differences in concentrations were evident for some metals, none of the differences were found to be significantly higher for samples associated with sludge material from this area in comparison to background subsurface soil (Appendix D of the RI).

Cyanide was not detected in any of the samples. The organic content in samples from BH-01 (2 to 8 feet) and BH-03 (16 to 20 feet) was 3.0 and 0.5%, respectively. Grain-size distribution for these samples shows that sand is the predominant fraction (61.4 to 79.9%), with some silt (14.1 to 29.4%), and only small percentages of gravel and clay (5.5 to 6.8% and 0.4 to 2.3%, respectively).

Bulky Waste Area Results. One soil boring (BH-06) was located in the Bulky Waste Area. During drilling, a large amount of refuse was encountered from 0 to 6 feet, which was underlain by glacial outwash from 6 to 20 feet. The types of refuse identified included nylons, paper, bottles, wire, and black organic (decomposed) material. Two samples were collected: one from 2 to 4 feet and a second from 6 to 10 feet.

One volatile organic (acetone) and one pesticide (4,4'DDE) were detected at this boring. No semivolatile organics or PCBs were found at either of the depths. A summary of the organic compounds is presented in Figure 8.

Acetone was detected at concentrations of 350 and 48 µg/kg at 2 to 4 feet and 6 to 10 feet, respectively. This compound was also found in landfill gas at other portions of this disposal area. 4,4'-DDE was detected at 4.6 µg/kg in the 2-to-4-foot sample. The detection of this pesticide is most likely attributed to the materials disposed of in the Bulky Waste Area, although 4,4'-DDE was also found in background surface soil at a lower concentration.

Major-metal ions (aluminum, iron, magnesium, and potassium) were detected in both samples at the highest concentrations (401 to 9,530 mg/kg). Barium, beryllium, and seven heavy metals [chromium (3 to 6.3 mg/kg), cobalt (3.5 mg/kg), copper (3.3 to 4.1 mg/kg), lead (4.5 to 61.4 mg/kg), mercury (0.2 to 0.24 mg/kg), vanadium (6.7 to 11.3 mg/kg), and zinc (18.9 to 95.9 mg/kg)] were also detected in both samples. In addition, antimony was found at 6.0 mg/kg from 6 to 10 feet, and manganese was found at 116 mg/kg from 2 to 4 feet. Concentrations of individual metals were usually near or within the range detected in background samples. Concentrations of mercury were less than two times greater, and lead and zinc were as much as five times higher than those in the background. Even though some of these metal concentrations were elevated, it cannot be demonstrated that there is any significant difference between concentrations in these subsurface soil samples compared to those in background subsurface soil

(Appendix D of the RI).

Cyanide was not detected in either sample. The grain-size distribution and TCO analysis conducted on BH-06 (6 to 10 feet) indicate that sand (59.8%) was the largest fraction present, followed by silt (29.8%), gravel (8.8%), and clay (5.5%). An organic content of 1.0% was also measured.

Solid Waste Area Results. One soil boring (BH-07) was drilled at the southern end of the Solid Waste Area. A strong refuse odor was present during drilling activities, and organic vapors ranging from 30 to 300 ppm occurred. Assorted refuse, including household garbage, milk cartons, plastic, and paper, was encountered throughout the entire 20 feet of the boring. Both samples (4 to 8 feet and 14 to 18 feet) collected from this boring contained refuse material.

Volatile organics were not detected in either sample collected from BH-07 because of elevated detection limits that may have masked detectable concentrations. This was discussed in more detail in section 2.6.2 of the RI. However, semivolatile organics, pesticides, and PCBs were detected.

Even though volatile organics were not identified in subsurface soil, landfill gas (section 4.2.8 of the RI) and surface soil data indicate that aromatic and chlorinated volatiles were present in a large range of concentrations throughout most of the Solid Waste Area. Ketones were also identified in these media.

Semivolatile organics (PAHs, phthalates, dichlorobenzenes, and phenols) were found in the two samples collected at BH-07. Seven different PAHs (naphthalene, 2-methylnaphthalene, phenanthrene, fluoranthene, pyrene, benzo(a)anthracene, and chrysene) were detected from 4 to 8 feet. Three PAHs (naphthalene, 2-methylnaphthalene, and phenanthrene) were also found in the sample collected from 14 to 18 feet. When detected, individual PAH concentrations were higher at the 14 to 18 foot depth.

Two dichlorobenzenes (1,2-dichlorobenzene and 1,4-dichlorobenzene) were found from 4 to 8 feet at 240 and 97 μg/kg, respectively. Two phenols, consisting of 2-methylphenol and 4-methylphenol, were detected from 4 to 8 feet at 260 μg/kg and from 14 to 18 feet at 4,000 μg/kg, respectively. Dichlorobenzenes and methylphenols (creosols) have many uses including uses as disinfectants, moth control agents, synthetic resins, and wood preservatives. A variety of mixtures containing methylphenols include degreasers and cutting oils. Dichlorobenzenes are also used in pesticides, waxes, and agricultural chemicals. Because of the various uses of these chemicals, municipal or industrial disposal to this area is probably the dominant source.

Five different phthalate compounds (diethylphthalate, di-n-butylphthalate, bis(2-ethylhexyl)phthalate, di-n-octylphthalate, and butylbenzylphthalate) were found in both samples from BH-07 at concentrations ranging from 96 to 18,000 μg/kg. Total phthalate concentrations were generally higher in the sample collected from 14 to 18 feet (25,000 μg/kg) than in the sample collected from 4 to 8 feet (2,556 μg/kg). Given that phthalate concentrations were higher in the subsurface soil than in other soils in the study area, coupled with the types of refuse found, these phthalates may be attributed to the materials deposited in this disposal area.

Five pesticides detected from 14 to 18 feet included 4,4'-DDD (26 μg/kg), 4,4'-DDE (12 μg/kg), dieldrin (14 μg/kg), *alpha*-chlordane (17 μg/kg), and *gamma*-chlordane (15 μg/kg). Only 4,4'-DDE was found from 4 to 8 feet (12 μg/kg). Although these pesticides have been found in other surface and subsurface soils in the Site study area, it is likely that they are associated with the buried refuse in the Solid Waste Area.

Two PCB aroclors, 1242 and 1254, were detected in samples from BH-07. Aroclor-1242 was detected at 310 μg/kg in the sample collected from 14 to 18 feet, while aroclor-1254 was detected at 270 μg/kg in the sample collected from 4 to 8 feet. PCBs were also detected in monitoring wells MW-08-01, MW-08-02, and MW-05-01 (section 4.2.4 of the RI), although a different aroclor was identified. The primary use of PCBs is in capacitors and transformers. Aroclor-1242 was also used in light ballasts, and aroclor-1254 was also used in small appliances. Because disposal of PCBs was not regulated until 1978, it is possible that materials containing PCBs could have been disposed of during landfill operations.

In addition to the organic compounds, major-metal ions (aluminum, iron, magnesium, and potassium), barium (16 to 22.9 mg/kg), beryllium (0.39 to 0.7 mg/kg), chromium (5.5 mg/kg), cobalt (1.8 to 3.3 mg/kg), copper (7.4 to 18.9 mg/kg), lead (19.4 to 20.2 mg/kg), mercury (0.18 to 0.39 mg/kg), vanadium (5.5 to 9.3 mg/kg), and zinc (45.5 to 68.2 mg/kg) were detected in both the samples. Concentrations ranged from 3,620 to 5,250 mg/kg for aluminum, 4,800 to 7,540 mg/kg for iron, and 618 to 1,090 mg/kg for basic cations. Antimony was also detected from 4 to 8 feet (6 mg/kg). In comparison to background subsurface soil concentrations, mercury and lead concentrations were about two times greater, zinc was about three times greater, and copper was about five times greater. These differences, however, were not found to be statistically significant in relation to background surface soil. The sample analyzed for grain size and TCO was predominantly sand (60.7%) with 27.6% silt, 8.1% gravel, and 3.5% clay. The organic content of this sample was 3.8%.

B. Groundwater

Groundwater was collected from shallow and deep overburden and bedrock monitoring wells along with residential wells in the vicinity of the Site study area. Eight existing monitoring wells and nine residential wells were sampled during June 1991. M&E installed 28 additional monitoring wells from July to September 1991. These were selectively sampled along with existing monitoring wells and nine residential wells during September/October 1991, January/February 1992, and April 1992. Samples submitted during these four rounds of sampling were analyzed for the following parameters:

- Volatile organics
- Semivolatile organics
- Water-soluble organics (only September/October 1991, January/February 1992, and April 1992)
- Pesticides and PCBs
- Metals (unfiltered and filtered)
- Cyanide
- Sulfide (only June 1991, September/October 1991, and January/February 1992)
- Ammonia (only April 1992)
- Total organic carbon (TOC)
- Biochemical oxygen demand (BOD)

Four wells sampled during this investigation were known to be in waste material in one of the disposal areas. Three of the wells are located in the Solid Waste Area (MW-14-01, OW-25, and OW-27); the fourth well, MW-02-01, is located in the Sewage Sludge Area. A fifth well, MW-V, appears to be located within the boundaries of the Bulky Waste Area; however, drilling logs for this well were not available to confirm this. For this reason, MW-V is not considered to be in waste material. All of the other monitoring wells were installed outside of the disposal area boundaries for further characterization of the potential migration contaminants and ground water flow paths.

Summary of Groundwater Findings. Numerous organic compounds were detected in the different groundwater flow zones. The types of compounds ranged from volatile organics to compounds that were less volatile and soluble (semivolatiles, pesticides, PCBs) to compounds that were more soluble (water-soluble organics). Of these compounds, volatile organics, primarily chlorinated and aromatic volatiles, were frequently and consistently detected in groundwater throughout the study period.

The aerial and vertical extent of volatile organics in groundwater is shown in Figures 9 and 10. More elevated concentrations generally occurred in the vicinity of the Solid Waste Area. Less elevated concentrations occurred in the vicinity of the Bulky Waste Area, and even lower concentrations occurred in the vicinity of the Sewage Sludge Area. The predominant groundwater flow direction through the Site study area is toward the south and southeast. Immediately downgradient of the Solid Waste Area, volatile organics were present in elevated concentrations. Further downgradient, and east of Mitchell Brook, concentrations tended to decrease. Volatile organics were still present, though at lower concentrations, south of the transfer station road. However, further south towards Saugatucket Road, volatile organics were not found in the residential well (Resident #6).

Volatile organics also occurred to the north of the Solid Waste Area as well as to the northeast in two residential wells. These compounds were also found to the west of Rose Hill Road near the northern portion of the Solid Waste Area, but not to the northwest in the vicinity of Resident #11. West of Rose Hill Road, near the southern portion of the Solid Waste Area, volatile organics were not found. To the north, volatile organics were found as far north as the north side of Mitchell Brook, but were not detected in the most northern residential well (Resident #1).

East of the Bulky Waste Area, concentrations decreased even more, and south of the Bulky Waste Area, one compound was found at a low concentration during only one sampling round.

In comparison to concentrations measured in wells located in the Solid Waste Area, volatile organic concentrations found in the Sewage Sludge Area were relatively low. East of the Sewage Sludge Area, volatiles were found at slightly higher concentrations, but this was not consistent.

East of the Saugatucket River, volatile organics were not detected in the lower overburden groundwater, but were found infrequently in residential wells at relatively low concentrations. The source of the volatiles in the residential wells, however, is not entirely clear.

Throughout the Site study area, the chlorinated volatiles detected most often and in the highest concentrations were 1,1-DCA (range of 1 to 220 ug/L), 1,2-DCE (3 to 730 ug/L), vinyl chloride (3 to 690 ug/L), and chloroethane (4 to 86 ug/L). In comparison, the lower concentrations of the more chlorinated volatiles (i.e., TCE, PCE, 1,1,1-TCA) suggests that degradation processes are active. While this is very likely because of degradation of landfill wastes, it is also possible that these compounds were disposed of in industrial and municipal wastes, given the elevated concentrations detected. These compounds are components of consumable products but are used in larger quantities as solvents in industrial applications. Aromatic volatiles, primarily BTEX compounds, were also found in most of the wells. Tables 9 through 16 summarize the chemicals detected in ground water.

Although prevalent, volatile concentrations appear to have decreased to some extent since landfill operations ceased. During previous studies, the highest concentrations were measured between 1981 and 1982 , and by 1984 concentrations had decreased by as much as several orders of magnitude. Concentrations detected during this investigation varied depending upon location within the Site study area. During RI, the highest concentrations detected for the organic compounds listed in the historical data set were generally well below the concentrations detected up to 1982, but in many wells, concentrations were higher than found in 1984.

Although variations in volatile organic concentrations occurred over the study period, specific trends were not evident with the available data. This is not unexpected, since the source of these compounds is wastes from within the disposal areas. Given the nature of landfills, with their heterogeneous deposits of wastes and decomposition and biological transformations, the types of and concentrations of compounds released to groundwater are expected to vary to some degree.

Since landfill operations stopped in 1983, the decreases that have occurred are likely related to the slower release of contaminants from source materials (landfill contents).

The detection of *N,N*-DMF in wells west of Rose Hill Road and north of Mitchell Brook confirms that movement of groundwater in these directions is occurring. This compound and acrylamide were also found in several wells directly in and immediately downgradient of the Solid Waste Area, where disposal of industrial wastes, primarily solvents and adhesive glue wastes, have been documented. An explanation for presence of *N,N*-DMF in Residence #8 during one sampling round is not apparent. However, the concentration detected was well below the method detection limit.

The predominant metals detected in groundwater, regardless of flow zone or location, were aluminum, iron, basic cations (calcium, magnesium, sodium, and potassium), barium, and manganese. For the most part, the more soluble forms of these metals were found in higher concentrations than insoluble forms. The types of metals and concentrations detected were similar between the shallow and deep overburden groundwater. Heavy metals found at least once in these flow zones include antimony, arsenic, cadmium, chromium, cobalt, copper, lead, nickel, mercury, vanadium, and zinc. Beryllium was also detected. The number of metals and concentrations were significantly lower in bedrock groundwater. In this flow zone, major-metal ions along with barium and manganese were typically the only metals detected. A few heavy metals (zinc, nickel, copper) were occasionally found.

In shallow overburden groundwater in and immediately downgradient of the Sewage Sludge Area, metals that exceeded concentrations compared to background wells were generally basic cations, iron, barium, and manganese. Occasionally other heavy metals (arsenic, lead, nickel, vanadium, and zinc) were found in higher concentrations than background. Elevated metal concentrations were also found downgradient of the Solid Waste Area, west of Mitchell Brook. However, none of these exceedances were found to be statistically significant based on the available data. In deep overburden groundwater, elevated concentrations and a larger number of heavy metals were exhibited by groundwater directly in and west of the Solid Waste Area.

In bedrock groundwater, significantly elevated concentrations of basic cations, aluminum, barium, and manganese were found in relation to background groundwater. In addition, a few heavy metals (chromium, nickel, vanadium, and zinc) that were not detected in background groundwater were found. In several residential wells (overburden and bedrock) particularly to the north and northeast of the Solid Waste Area, and east of the Saugatucket River, manganese was the metal that most often exceeded background concentrations.

C. Surface Water

Eighteen surface water locations were sampled during the study period. This includes surface water from Mitchell Brook, the Saugatucket River, the unnamed brook, and an unnamed tributary to Mitchell Brook. The unnamed brook was sampled west of Rose Hill Road at SW-10. Located north of the disposal areas, SW-01 was sampled in an unnamed tributary that feeds into Mitchell Brook. Along Mitchell Brook, seven locations were sampled: SW-07, SW-09, SW-12, SW-13, SW-14, SW-15, and SW-16. In the Saugatucket River nine locations were sampled: SW-02, SW-03, SW-04, SW-05, SW-06, SW-08, SW-11, SW-17, and SW-18. Surface water sampling locations are shown in Figure 11. Surface water samples were analyzed for the following parameters:

- Volatile organics
- Semivolatile organics
- Water-soluble organics (only September/October 1991, January/February 1992 and April 1992)
- Pesticides and PCBs
- Metals (unfiltered and filtered)
- Cyanide
- Sulfide (only June 1991, September/October 1991, and January/February 1992)
- Ammonia (only April 1992 and May 1992)
- Total organic carbon (TOC)
- Biochemical oxygen demand (BOD)

Other water quality parameters measured during field activities include dissolved oxygen, conductivity, and pH.

The analytes detected in surface water are presented in Tables 17 through 21. A summary of the organic compounds and metals detected in surface water samples is presented in Figures 12 and 13.

Surface Water Results Summary. A few organic compounds were infrequently detected in low concentrations in the three surface water bodies: Mitchell Brook, the Saugatucket River, and the unnamed brook. Volatile organic compounds, primarily carbon disulfide and chlorinated and aromatic VOCs, were the major contaminants found. A few SVOCs and pesticides and a water-soluble organic, acrylamide, were also detected. Several surface water locations that were adjacent to leachate seeps and downgradient of the Solid Waste Area exhibited high metal concentrations.

Unnamed Brook. One location in the unnamed brook was sampled in June and September/October 1991 and January/February 1992 (Figure 11). The unnamed brook was not sampled during the other two rounds, April and May 1992. The sampling location (SW-10) is west of Rose Hill Road and southwest of the Solid Waste Area. An active sand and gravel operation is located directly upstream of this location.

The only organic compounds detected at this location during the study period were one volatile organic, carbon disulfide, at 6 $\mu g/L$ in January/February 1992 and one pesticide, *gamma*-BHC, at

0.002 $\mu g/L$ in September/October 1991. Both of these concentrations were less than sample quantitation limits. Semivolatile organics, water-soluble organics, and PCBs were not detected.

During the study period, major-metal ions as well as barium and manganese were generally the only metals detected. While concentrations of these metals varied slightly, a large fraction of the concentrations was associated with the more soluble forms of these metals. Aluminum was not detected in filtered samples and was reported once at 160 µg/L in unfiltered samples. In unfiltered samples, iron concentrations ranged from 5,140 to 6,160 µg/L, basic cation concentrations ranged from 2,060 to 11,100 µg/L, barium concentrations ranged from 24.9 to 31.6 µg/L, and manganese concentrations ranged from 905 to 1,690 mg/L. Concentrations in filtered samples ranged from 3,325 to 3,660 µg/L for iron, from 2,800 to 12,100 µg/L for basic cations, from 22.7 to 30.2 µg/L for barium, and from 789 to 1,740 µg/L for manganese. In addition, zinc was found in January/February 1992 at 17.2 $\mu g/L$ in the unfiltered sample and at 14.9 $\mu g/L$ in the filtered sample.

Cyanide was not detected, while sulfide was measured at 1.9 mg/L in June 1991. Total organic carbon and BOD were not detected. Conductivities ranged from 26 to 146 μmhos/cm, pH values ranged from 5.9 to 7.2, and DO ranged from not detected to 8.4 mg/L during the study period.

As discussed above, different pesticides (such as *gamma*-BHC) that are not necessarily related to the disposal areas were detected at low concentrations. This brook is not expected to be affected by the disposal areas, since it is upgradient and was found to be consistently losing water to groundwater during the study period. However, there is a strong likelihood that alterations of metal concentrations are occurring because of the disturbance from the nearby sand and gravel operations, which are still active. Weathering of newly exposed soil and bedrock would result in increased releases of metals (including iron and aluminum) that would enter the brook. This is important, since this brook runs through the sand and gravel operations upstream of the sampling location, and new cuts in the sand bank reveal visually apparent, iron rich sands of natural origin.

Mitchell Brook. Along Mitchell Brook, seven locations were sampled from June 1991 to May 1992. Six of the locations were sampled in June and September/October 1991 and include SW-07, SW-09, SW-12, SW-13, SW-14, and SW-15. In addition, SW-01, which is located on the unnamed tributary that feeds into Mitchell Brook upstream of the disposal areas, was sampled during these rounds. In May 1992, only SW-07, SW-09, SW-12, and a new location established as SW-16 were sampled. The location on the unnamed tributary (SW-01) was not sampled in May 1992.

No organic compounds were found in the background location (SW-01) on the unnamed tributary, yet a few organic compounds were detected infrequently and at low concentrations (usually less than 10 $\mu g/L$) in Mitchell Brook. Carbon disulfide was detected more frequently than other compounds at concentrations below 10 $\mu g/L$. All of the other compounds detected were found in only one location during one sampling round; and consist of chlorinated (1,2-DCE and chloroethane) and aromatic (BTEX compounds and chlorobenzene) organics, and three phthalates [bis(2-ethylhexyl)phthalate, diethylphthalate, and di-n-butylphthalate]. In addition, acrylamide was found at 272 μg/L in SW-12. All of these compounds have also been found in different media in the vicinity of the disposal areas.

Most of the organic compounds were detected at SW-12, which is the most downstream location on Mitchell Brook, prior to its confluence with the Saugatucket River. The presence of organic compounds coincides with higher BOD levels measured at this location. In particular, acrylamide, which was also found in groundwater immediately downgradient of the Solid Waste Area and near Mitchell Brook (MW-04), was possibly disposed of with industrial waste, indicating that groundwater may be affecting water quality in this stream. Similarly, the compounds detected in SW-12 are similar to those found in MW-11, which is located near Mitchell Brook. Likewise, the xylene detected in SW-07 was similar to the types of aromatic volatiles (BTEX compounds) found at MW-11.

The predominant metals detected include major-metal ions, barium, and manganese. As shown in Figure 14, the highest concentrations of unfiltered metals were consistently found south of the transfer station road and downstream of the disposal areas, near SW-07, and increased near SW-12. This coincides with the extensive orange staining, precipitate, and floc covering of sediment in the brook south of the transfer station road. Insoluble forms of these metals were associated with these locations, whereas more soluble forms were dominant at upstream locations, north of the transfer station road. Conductivities also increased in a downstream direction. Concentrations of iron, manganese, basic cations, and conductivities were found to be significantly higher at these locations compared to the background location on the unnamed tributary. Metal concentrations and conductivity also increased, but were less pronounced, at SW-15. Other metals (zinc, antimony, copper, and lead) were occasionally found at lower concentrations in Mitchell Brook.

These trends, coupled with the organic compounds detected at SW-12, indicate that groundwater may be contributing to downgradient migration from the disposal areas to Mitchell Brook. Shallow and deep overburden groundwater exhibited elevated metal concentrations in the vicinity of the Solid Waste and Bulky Waste Areas. These flow zones discharged to Mitchell Brook throughout the study period. Overland flow to Mitchell Brook may also be occurring. The metals detected and concentrations varied over the study period, but there were no recognizable seasonal trends.

Saugatucket River. Nine locations were sampled in the Saugatucket River over five sampling rounds from June 1991 to May 1992. Six locations were sampled in June 1991: SW-02, SW-03, SW-04, SW-05, SW-06, and SW-08. Surface water location SW-11 was added in September/October 1991, and locations SW-17 and SW-18 were added in May 1992.

A few organic compounds were detected at low concentrations (less than 14 μg/L) in the surface water locations on Saugatucket River. Besides carbon disulfide, which was detected the most frequently, xylene and pesticides (4,4'-DDD and methoxychlor) were each detected once during the study period. Coupled with DOs above 5 mg/L and BOD values near zero, there was no indication that the disposal areas were substantially contributing organics to this river during the study period.

On the other hand, increases in metal concentrations along the course of the river appear to be influenced by the disposal areas, especially the Bulky Waste Area. For the most part, major-metal ions, manganese, and barium were the primary metals detected consistently throughout the study period. The largest fraction of these metals appears to be in a more soluble form based on comparisons of unfiltered and filtered sample concentrations.
Of these, iron and manganese as well as conductivities were found to be significantly elevated in leachate along the eastern perimeter of the Bulky Waste Area and the banks of the Saugatucket River.

Figure 15 shows the trends from upstream to downstream for unfiltered metal concentrations along the Saugatucket River. For aluminum, there was no recognizable trend, as concentrations constantly increased and decreased between sampling locations. In contrast, iron and manganese concentrations gradually increased from the background location (SW-02) toward SW-03 and SW-04, which are primarily downgradient of the Sewage Sludge and Bulky Waste Areas, respectively. Concentrations for these metals peaked at SW-05, which is downgradient of several large leachate seeps that flow into the river at this point. Downstream concentrations then decreased to a level similar to that of SW-03 and SW-04, most likely because of dilution, and then remained near the same level or slightly increased again below the confluence of Mitchell Brook. Concentrations continued to increase beyond where the river approaches and flows past Saugatucket Road. These downstream increases are more pronounced for manganese and basic cations (calcium, magnesium, sodium, and potassium) than for iron and barium. Conductivities exhibit the same patterns. Differences were statistically confirmed for calcium, manganese, magnesium, sodium, and conductivity between several downstream locations and the background location.

Elevated concentrations of similar metals were also evident, although not significantly, in shallow overburden groundwater downgradient of each of the disposal areas. Since the predominant groundwater flow direction from the disposal areas (primarily the Sewage Sludge and Bulky Waste Area) is toward the Saugatucket River, groundwater discharges along with surface runoff (overland flow) to the river are likely mechanisms that contribute to the transport of these more soluble metals from those areas.

Differences in metal concentrations also occurred between sampling rounds. Metal concentrations in June 1991 were greater than in any other round. Iron and barium concentrations were about 20 times greater in June 1991 than in September 1991. Calcium, magnesium, sodium, and manganese were also four to six times greater in June 1991 than in September. This was particularly evident at SW-05. At this location, the higher concentrations during the June 1991 sampling round corresponded with low-flow conditions in combination with elevated metal concentrations from leachate seeps. Throughout the rest of the study period, concentrations varied, but not as substantially. Many of the mechanisms that likely contribute to these variations depend on precipitation (i.e., leachate composition, groundwater discharge, surface water volume, surface runoff).

Although the organic compounds detected in surface water in Mitchell Brook and the Saugatucket River were also found in other media in the Site study area, upstream to downstream trends were not exhibited since these compounds were seldom and inconsistently detected. However, the detection of acrylamide in Mitchell Brook, prior to its intersection with the Saugatucket River, indicates that transport of organic compounds in the Site study area is occurring at least this far south. More evident were the increases in metal concentrations in the Saugatucket River, near the large leachate seeps (along the eastern perimeter of the Bulky Waste Area), and in Mitchell Brook, south of the transfer station road. In particular, concentrations of iron, manganese, and other metals in these areas were found to be significantly elevated. Higher conductivities and the presence of orange floc were characteristic features in these areas. Below the confluence of Mitchell Brook and the Saugatucket River, metal concentrations decreased, although concentrations were higher than those found upgradient of the disposal areas.

D. Sediment

Eighteen sediment locations were sampled during the study period. This includes sediment from Mitchell Brook, the Saugatucket River, the unnamed brook, and an unnamed tributary to Mitchell Brook. The unnamed brook was sampled west of Rose Hill Road at SD-10. Located north of the disposal areas, SD-01, was sampled in an unnamed tributary that feeds into Mitchell Brook. Along Mitchell Brook seven locations were sampled: SD-07, SD-09, SD-12, SD-13, SD-14, SD-15, and SD-16. The Saugatucket River was sampled at nine locations: SD-02, SD-03, SD-04, SD-05, SD-06, SD-08, SD-11, SD-17, and SD-18. Sediment sampling locations are shown in Figure 11. Sediment sampling was conducted at the same time as surface water sampling. Sediment samples were analyzed for the following parameters:

- Volatile organics
- Semivolatile organics
- Pesticides and PCBs
- Metals
- Cyanide
- Sulfide (only June 1991 and September/October 1991)
- Ammonia (only May 1992)
- Total combustible organics (TCO)
- Grain size

The analytes detected in sediment are presented in Tables 22, 23, 24. A summary of the organic compounds and metals detected in sediment samples are presented in Figures 16 and 17. The analytes detected in each of the different areas (Table 3) are discussed in the following sections.

4.2.7.1 Unnamed Brook. One location in the unnamed brook (SD-10) was sampled for sediments in June and September/October 1991. This location corresponds with SW-10, which was also sampled at the same time. The analytes detected during June 1991 and September/October 1991 are summarized in Table 22 and Figures 16 and 17.

During September/October 1991, one volatile organic, 4-methyl-2-pentanone, was detected at 3 μg/kg. Seven pesticides were detected at concentrations below sample quantitation limits (0.23 to 2.6 μg/kg): *delta*-BHC, 4,4'-DDE, 4,4'-DDT, methoxychlor, endosulfan II, dieldrin, and *gamma*-chlordane.

Of the metals detected, iron concentrations (113,000 mg/kg) were substantially elevated above the others. Aluminum, followed by manganese and calcium (3,210, 1,150, and 1,070 mg/kg, respectively), were the next abundant. Magnesium, sodium, and potassium concentrations ranged from 2 to 415 mg/kg. Barium (64.6 mg/kg) and four heavy metals (lead at 7.4 mg/kg, nickel at 3.0 mg/kg, vanadium at 15.2 mg/kg, and zinc at 236 mg/kg) were also detected.

Sulfide was measured at 25 mg/kg, while cyanide was not detected. The sediment consisted primarily of sand (67.7%) and was intermixed with finer silt (18.8%) and clay (10.4%) grains. The organic content was 4.7%. No organic compounds, including volatile organics, semivolatile organics, pesticides, and PCBs, were detected.

The detection of several different pesticides including *delta*-BHC in September/October 1991 in sediments coincides with the detection of *gamma*-BHC in the associated surface water sample. Since these sediments are predominantly sand with little organic material, the retention of organic compounds (if present) is expected to be limited. During this same time, substantial increases in lead concentrations and the detection of other heavy metals occurred in sediment, but were not evident in surface water. This suggests that sediment transport from upgradient sources is possibly occurring. As discussed earlier, there is no hydrogeologic indication that the disposal areas are affecting this brook, which is west of Rose Hill Road. However, as also discussed above, nearby sand and gravel operations are likely affecting metal concentrations in the brook.

Mitchell Brook. Seven locations were sampled on Mitchell Brook from June 1991 to May 1992. Six of the locations were sampled in June and September/October 1991: SD-07, SD-09, SD-12, SD-13, SD-14, and SD-15. In addition, SD-01, which is located on the unnamed tributary that feeds into Mitchell Brook and is upstream of the disposal areas, was sampled during these rounds. In May 1992 a new location established as SD-16 was sampled. The location at the unnamed tributary was not sampled in May 1992.

Two volatile organics were detected during the June 1991 sampling round at concentrations below sample quantitation limits. Xylenes were detected at SD-07 (8 μg/kg) and at SD-09 (7 μg/kg).

Trichloroethane (9 μg/kg) was detected at SD-09. Semivolatile organics, pesticides, and PCBs were not detected at any location sampled. Sulfide was detected at all locations and ranged from 3.7 to 34 mg/kg, whereas cyanide was not detected at any of the locations. Sand was the predominant size fraction (57.3 to 97%). Organic content ranged from 0.8 to 7.0%.

Five volatile organics, consisting of chlorinated and aromatic volatiles and ketones, were detected at one or two locations during the September/October 1991 round of sampling. These include chloroform at SD-15 (5 μg/kg), and PCE at SD-14 (3 μg/kg) and SD-09 (2 μg/kg). Benzene (1 μg/kg) was detected at SD-12. The highest concentrations were for ketones, as acetone was detected at SD-07 and SD-09 (190 μg/kg and 200 μg/kg, respectively). Also detected at SD-07 was MEK (46 μg/kg).Sulfide was detected only at SD-12 (850 mg/kg) during the September/October 1991 sampling round, and cyanide was not detected at any of the locations. Based on grain-size distributions, sand was the predominant fraction (51.2 to 97.3%), and organic content ranged from 0.8 to 7.6%.

Three semivolatile organics and two pesticides were detected at two locations during this sampling round. PCBs were not detected at any locations. Di-n-butylphthalate (650 μg/kg) was detected at SD-09. Two PAHs, fluoranthene and pyrene, were also detected at SD-09 (34 and 40 μg/kg, respectively). Pesticides found at this location include 4,4'-DDD (8.2 μg/kg) and 4,4'-DDE (4.9 μg/kg). The same PAHs and pesticides were found at SD-15: fluoranthene (34 μg/kg), pyrene (40 μg/kg), and 4,4'-DDE (1.6 μg/kg).

Ammonia was also detected at SD-12 (25.6 mg/kg) and SD-16 (4.36 mg/kg) during May 1992. Cyanide was not detected at any of the locations. The predominant grain size at the locations was sand (86.5 to 95.7%). Organic content ranged from 1.1 to 1.8%.

More types of organic compounds were detected in sediment in Mitchell Brook than in the associated surface water. Organic compounds were not found at the background location on the unnamed tributary (SD-01). Ketones (acetone and MEK) and chlorinated volatiles (TCE, PCE, 1,2-DCE, and chloroform) and BTEX compounds were the primary types of volatile organics. Found more often and in higher concentrations were PAHs, phthalates, and pesticides (4,4'-DDE, 4,4'-DDD, and *delta*-BHC), since these compounds are less soluble and more strongly adsorb to sediment and organic material. All of these compounds were also found in other media near the disposal areas. Surface runoff (overland flow) and groundwater discharges to the brook are evident. With the exception of PAHs, which were found in several locations near roads and other areas of vehicular activity, there were no recognizable patterns of distribution.

On the other hand, metals exhibited several trends, from upstream to downstream as shown in Figure 18. For the most part, concentrations were not found to be significantly elevated compared to the background location on the unnamed tributary. For example, concentrations for aluminum and lead were highest at the most upgradient location, SD-13, which is upstream of the northern portion of the Solid Waste Area. Concentrations steadily decreased toward SD-16 and then increased at SD-07, which is south of the transfer station road, before decreasing a short distance downstream at SD-12. Barium exhibited a somewhat similar trend as aluminum and lead. On the other hand, iron and manganese concentrations were relatively similar along the length of brook from SD-13 to SD-09. Iron concentrations began to increase at SD-16. Iron concentrations continued to increase at SD-07, as did manganese. Lower concentrations for both these metals occurred further downstream at SD-12. Elevated concentrations south of the transfer station road correspond with elevated metal concentrations in surface water in this area as well as the presence of large amounts of orange floc and precipitate that cover the sediment.

Saugatucket River. Nine locations were sampled in the Saugatucket River from June 1991 to May 1992. Six locations were sampled in June 1991: SD-02, SD-03, SD-04, SD-05, SD-06, and SD-08. Sediment location SD-11 was added in September/October 1991, and locations SD-17 and SD-18 were added in May 1992.

Five volatile organics, consisting of chlorinated (TCE and 1,2-DCE) and aromatic volatiles (ethylbenzene and xylenes) and carbon disulfide, were detected at three locations during the June 1991 sampling round. Trichloroethene was detected at 7 μg/kg in SD-04 and increased downstream to 10 μg/kg at SD-06 and 150 μg/kg at SD-08, which is downstream of Saugatucket Road. Also detected at SD-08 was 1,2-DCE (5 μg/kg) and ethylbenzene and xylene (8 and 67 μg/kg, respectively). Xylene was also detected at 10 μg/kg in SD-03. Carbon disulfide was found at SD-08 (9 μg/kg). No volatile organics were detected at SD-02, the background location, or SD-05, which is downstream of SD-04.

Seven PAHs were detected at SD-08 (Table 22) at a total concentration of 1,410 μg/kg. This location is downstream of the Saugatucket Road. Another semivolatile organic, butylbenzylphthalate was detected at SD-06, also below the sample quantitation limit. Pesticides and PCBs were not detected.

Aluminum, iron, manganese, and barium were detected at all of the locations. At all of the downstream locations, concentrations of these metals were higher than in the background location, SD-02. Concentrations for aluminum ranged from 749 to 6,280 mg/kg. Iron ranged from 780 to 1,600 mg/kg, and barium and manganese ranged from 2.7 to 26.2 mg/kg and 13.5 to 193 mg/kg, respectively. Basic cation concentrations ranged from 115 to 1,270 mg/kg. The highest concentrations for these metals usually occurred at SD-04 and SD-05.

Also detected in downstream locations were arsenic (0.79 to 2.1 mg/kg) at SD-04, SD-05, and SD-08 and chromium (1.9 to 8.7 mg/kg) and cobalt (3.4 to 4.2 mg/kg) at SD-04, SD-05, and SD-06. Higher concentrations corresponded with SD-04 and SD-05. In addition, lead and zinc were detected at SD-06 (10.9 and 20.5 mg/kg, respectively), while selenium was found at SD-05 (2.1 mg/kg). Beryllium and nickel were detected at almost all locations at concentrations ranging from 0.4 to 2 mg/kg and 1.4 to 9.5 mg/kg, respectively. With the exception of beryllium and zinc, these metals were also detected at the background location, SW-02, at least once during the study period.

Sulfide was detected in all locations while cyanide was not found at any. Sulfide ranged from 15 to 129 mg/kg and was highest at SD-06. At SD-04 and SD-05, sediments largely consisted of sand (37.7 and 54.5%, respectively) and silt (48.5 and 42.5%, respectively). At other locations, the percentage of silt decreased and sand increased. Organic content ranged from 1.0 to 14.7%.

Volatile organics were also detected during the September/October 1991 sampling round, but the compounds were somewhat different from those found in June 1991. Aromatic volatiles, ethylbenzene (3 μg/kg), and xylene (8 μg/kg) were found at SD-05. Acetone was detected at two locations: SD-03 (210 μg/kg) and SD-08 (215 μg/kg). Three other volatile organics were found at SD-08: MEK (28 μg/kg), PCE (4 μg/kg), and carbon disulfide (22 μg/kg). In addition, pyrene was detected in SD-03 at 39 μg/kg. Pesticides and PCBs were not detected at any of the locations.

During this sampling round, major-metal ions, manganese, and barium were detected at higher concentrations downstream of the background location. In the background location, SD-01, concentrations of aluminum were 8,650 mg/kg, iron were 1,500 mg/kg, basic cations were 350 to 373 mg/kg, and barium and manganese were 21.5 and 113 mg/kg, respectively. The iron concentration at SD-06 was 8,940 mg/kg, and iron and aluminum concentrations at SD-04 (6,780 and 16,400 mg/kg, respectively) and SD-05 (8,420 and 6,170 mg/kg, respectively) were more elevated than those at the other locations (1,260 to 3,080 and 1,020 to 2,590 mg/kg, respectively). Basic cation concentrations ranged from 242 to 2,560 mg/kg, barium ranged from 3.1 to 30.5 mg/kg, and manganese ranged from 41.1 to 422 mg/kg. Concentration ranges for these metals were slightly higher than ranges in June 1991.

Other metals detected include arsenic (0.43 to 1.2 mg/kg), (chromium 11.4 to 18.1 mg/kg), cobalt (1.9 to 6.5 mg/kg), lead 4.3 to 24.2 mg/kg), nickel (12.8 to 20 .5 mg/kg), selenium (0.37 to 1.3 mg/kg), vanadium (2 to 17.7 mg/kg), and zinc (43.6 to 49.8 mg/kg). Beryllium (2.3 mg/kg) was detected at SD-04. Four of these metals were also detected at SD-02: lead at 7.2 mg/kg, selenium at 0.52 mg/kg, and vanadium at 2 mg/kg. Higher concentrations of these metals were found in at least one location downstream.

Four PAHs (phenanthrene, anthracene, fluoranthene, and pyrene) were detected at a total concentration of 241 μg/kg in SD-11 during the May 1992 sampling round. Three pesticides were also detected in the sediments during this sampling round. The one detected most frequently was *delta*-BHC, which was found in all six of the downstream locations (0.46 to 1.3 μg/kg), but was not detected in the background location, SD-02. Detected at higher concentrations were 4,4'-DDE at 4.3 μg/kg and 4,4'-DDD at 8.0 μg/kg in SD-11, the location with PAHs. 4,4'-DDE was also detected at SD-18 at 1.2 μg/kg.

Major-metal ions were the predominant metals found during the May 1992 sampling round. Concentrations of aluminum were 836 to 1,860 mg/kg. The most elevated iron concentrations detected during this round were at SD-05 (25,900 mg/kg) and SD-06 (12,500 mg/kg). Iron ranged from 885 to 25,900 mg/kg. Basic cation (258 to 555 mg/kg), barium (2.9 to 13.7 mg/kg), and manganese (22.6 to 200 mg/kg) concentrations were similar to those detected during June 1991. Chromium and lead were detected at all locations from 1.1 to 2.5 and 3.7 to 13.5 mg/kg, respectively. Arsenic (2 to 6.1 mg/kg), cobalt (0.91 to 1.4 mg/kg), and selenium (0.43 to 0.58 mg/kg) were also found, but less frequently (two to four locations). Nickel was detected in SD-06 at 4.7 mg/kg, while vanadium and zinc were detected at 3.4 and 11.2 mg/kg, respectively, in SD-05.

During the May 1992 sampling round, cyanide was not found at any locations. Ammonia was detected in three locations with the maximum at SD-05 at 3.17 mg/kg. Sand was the predominant size fraction (64.6 to 95.8%) in sediment at each location, and organic content continued to be relatively low (1.3 to 5.6%).

The types of organic compounds detected in Saugatucket River sediment were also detected in the disposal areas and other media during the study period and include chlorinated and aromatic volatiles, ketones, carbon disulfide, PAHs, and pesticides. Most notably, TCE was detected at several locations along the river. The less soluble organics, like PAHs and pesticides, as well as volatile organics were detected more often in sediments than in the associated surface water.

When detected, organic compounds were predominantly found at SD-08 and SD-11. Both of these locations are near Saugatucket Road and were sampled in areas where the river widens and current is slower. As a result, suspended sediment tends to settle out here. In June 1991, volatile organics were primarily found along with PAHs at SD-08, which is located downstream of Saugatucket Road. This suggests that organic compounds and metals detected in this section of the River are probably more related to the road than to other sources.

For the most part, all of the metals detected in sediment were also found in the background location during the study period. Iron and aluminum were the predominant metals. As shown on Figure 19, the concentrations were generally consistently higher at SD-04 and SD-5, and coincided with higher concentrations in surface water at these locations. Both are immediately downgradient of the large leachate seeps east of the Bulky Waste Area. Orange floc and precipitate covering the sediment in this area were also present. Concentrations for these metals were also elevated at SD-06, below the confluence of Mitchell Brook, although surface water concentrations at this location were not. Lead, on the other hand, was lower at these locations and in general did not exhibit any discernable pattern. In relation to background concentrations, concentrations of lead, barium, manganese, and iron were significantly elevated at most of the downstream locations (SD-04, SD-05, SD-06, SD-08, SD-11). Iron and manganese concentrations at SD-03 were also found to be significantly higher. As discussed above, elevated metal concentrations near Saugatucket Road (SD-08 and SD-11) can be attributed to the road.

All metals were generally at the highest concentrations in September/October 1991. This corresponds with higher concentrations in surface water during the same period and may be somewhat related to seasonal variations. Following drier summer periods, metal concentrations generally increased during lower flow periods, when groundwater discharge accounts for a larger portion of a stream's volume.

E. Leachate

During the study period, leachate seeps were observed around the Solid Waste and Bulky Waste Areas. Leachate was collected from six locations at which seeps were present. Five of the leachate seeps (LE-02 to LE-06) were located between the Bulky Waste Area and the Saugatucket River. The other seep (LE-01) was just north of the Solid Waste Area, near Mitchell Brook. Leachate locations are presented on Figure 20. Historically, leachate seeps have been identified at the disposal areas by aerial photographs (United States Environmental Protection Agency 1987a, 1991a). In the past, a resident has reportedly observed leachate seeps with sulfur odors and varying colors and quantities west of Rose Hill Road, near the northern portion of the Solid Waste Area. At the Bulky Waste Area, a trench filled with crushed stone was reportedly dug to drain water to the Saugatucket River (RIDEM 1992a). During the field investigation a crushed-stone trench running vertically along the eastern bank of the Bulky Waste Area toward the Saugatucket River was observed. In addition, colored leachate originating from the hill slope near the Bulky Waste Area has been observed.

All six leachate locations (LE-01 to LE-06) were sampled during June 1991. Three additional composite samples were collected from the seep at LE-05 during April 1992, to supplement ecological toxicity testing. Samples were analyzed for the following parameters:

- Volatile organics
- Semivolatile organics
- Water-soluble organics (April 1992 only)
- Pesticides and PCBs
- Metals (unfiltered and filtered)
- Cyanide
- Sulfide (June 1991 only)
- Ammonia (April 1992 only)
- Total organic carbon (TOC)
- Biochemical oxygen demand (BOD)

The analytes detected in leachate are presented in Tables 25 and 26. A summary of the organic compounds and metals detected in leachate samples is presented in Figures 21 and 22. The analytes detected in each of the different areas (Table 3) are discussed in the following sections.

Saugatucket River. Five leachate seeps (LE-02 through LE-06) were sampled along the western bank of the Saugatucket River. Several large outbreaks of leachate were obvious because of orange-colored puddles of water and orange-stained soil and vegetation. The size of the seeps varied, with LE-03, LE-05, and LE-06 comprising the largest areas. Large clumps of orange floc were also observed near the seeps. It was reported that gravel-filled trenches were embedded along the eastern perimeter of the Bulky Waste Area to facilitate drainage from this disposal area.

In the June 1991 sampling effort, chlorinated and aromatic volatiles were detected in three of the five leachates seeps near the Bulky Waste Area. Chlorinated volatiles, 1,1-DCA and chloroethane, were each found at LE-03, LE-04, and LE-05 at concentrations below sample quantitation limits (2 to 8 μg/L). Aromatic volatiles, toluene, and chlorobenzene were also detected in these samples, although toluene was the only chemical detected above sample quantitation limits (27 to 50 μg/L). The highest toluene concentration occurred at LE-03. Each of these leachate seeps was approximately 50 feet downgradient of the Bulky Waste Area and within a few feet of the Saugatucket River. Although volatile organic concentrations were relatively low in leachate, elevated concentrations of chlorinated and aromatic volatiles were found in landfill gas in the Bulky Waste Area. Similar types of volatile organics have also been detected in soil and groundwater downgradient of this disposal area.

Carbon disulfide was the only organic detected in LE-02 (3 μg/L), located south of LE-05 and the Bulky Waste Area. The most northern leachate sampling location, LE-06, had no detectable concentrations of volatile organics, yet bis(2-ethylhexyl)phthalate was detected at 230 μg/L. Organic compounds, at similar concentrations, were found periodically in surface water and sediment in the Saugatucket River during the study period.

Metals detected in the highest concentrations in unfiltered samples were the major-metal ions [aluminum (184 to 9,220 μg/L), iron (15,200 to 1,370,000 μg/L), calcium (10,000 to 59,000 μg/L), magnesium (2,420 to 16,100 μg/L), sodium (5,560 to 55,400 μg/L), and potassium (2,000 to 44,800 μg/L)]. Other metals detected in all of the samples consist of barium (22.2 to 2,120 μg/L) and manganese (2,490 to 14,700 μg/L). Cobalt (5.6 to 295 μg/L) was detected in four samples (LE-02, LE-04, LE-05, and LE-06). Vanadium (22.2 to 65.2 μg/L) and zinc (34.4 to 133 μg/L) were each found in two samples (LE-02 and LE-05, and LE-02 and LE-03, respectively). Beryllium and lead were detected in only one sample, LE-02, at 8.7 and 174 μg/L, respectively. Metals were usually detected more often and at higher concentrations at LE-02 than in any of the other unfiltered leachate samples. This sample was collected in an orange-stained muddy area along seismic line S-5.

Fewer metals were detected in filtered samples. Again major-metal ions were found in all samples in the highest concentrations. Barium and manganese were also detected, and cobalt was found at LE-04. Because of the smaller number of metals and the lower concentrations found in filtered samples, the largest fraction of the metals are likely adsorbed onto soil or other particles, are in a colloidal phase or floc, or are present in less soluble or insoluble forms.

Cyanide was detected in the most northern (LE-06) and the most southern (LE-02) leachate seeps at 41.7 and 36.1 μg/L, respectively. Sulfides were not found in any samples. Biochemical oxygen demand was measured in LE-06 and LE-02 at 7.5 and 51 mg/L, respectively. High BOD indicates organic contamination. The BOD measured in these samples is consistent with the levels of organics found.

In April 1992, the leachate seep at LE-05 was sampled on three consecutive days to supplement ecological toxicity testing. The analytes detected in April 1992 are summarized in Table 26. Water-soluble organics, pesticides, and PCBs were not detected at this location. Although slightly different sampling methods were used to collect samples during this round, analytical data between the two rounds were fairly similar and are therefore comparable.

The types of organic compounds detected during this sampling round were similar to those found at LE-05 in June 1991. Ethylbenzene (1 to 2 μg/L) was found on all three days and xylenes on two days (2 to 3 μg/L). Chloroethane and 1,2-DCE were each detected once at 2 and 1 μg/L, respectively. Naphthalene and diethylphthalate were each detected on all three days at concentrations ranging from 0.7 to 0.9 μg/L and 4 to 11 μg/L, respectively.

In unfiltered samples, major-metal ions consisting of aluminum (239 to 623 μg/L), iron (49,000 to 283,000 μg/L), calcium (16,700 to 23,000 μg/L), magnesium (5,710 to 7,220 μg/L), sodium (20,800 to 24,700 μg/L), and potassium (12,000 to 15,200 μg/L) were found, all three days, at concentrations elevated above other metals. Barium (97.4 to 293 μg/L) and manganese (1,490 to 2,410 μg/L) were also detected each day. Chromium, lead, mercury, and zinc were each detected once at 5, 10.5, 0.2, and 8.1 μg/L, respectively. In filtered samples, major-metal ions, barium, and manganese were also detected daily. Concentrations were generally highest on the second day of sampling. In addition, vanadium and cobalt were not detected during this sampling round, though they were found at this leachate location in June 1991.

Cyanide was not found. Ammonia was detected from 5.06 to 22.6 μg/L. Total organic carbon ranged from 30.9 to 49.9 mg/L, levels that were higher than in June 1991. Likewise, BOD values ranged from 1.5 to 4.2 mg/L, though BOD wasn't detected in June 1991. A pH of 6.5 and conductivity of 412 were recorded, and hardness varied between 65 and 87 mg/L $CaCO_3$. Differences in chemical composition of leachate from June 1991 to April 1992 are evident, but for the most part, these differences appeared to be minor. Chlorinated and aromatic volatiles and phthalates were detected in both sampling rounds, although the individual chemicals sometimes varied. Similar types of metals were generally found, and there was no noticeably consistent difference in concentrations. In contrast, the physical character of the seeps varied. In June 1991, large quantities of floc and water volume emerging from the seeps were evident in the Saugatucket River area. In April 1992, this was less evident. This could have resulted from changes in precipitation, as groundwater and surface water levels were higher in April 1992 than in June 1991.

Mitchell Brook. A small leachate seep, LE-01, located along the northern slope of the Solid Waste Area, was sampled in June 1991. Orange-staining of ground material was present at the sampling location.

Four chlorinated volatiles were detected: 1,2-DCE (44 µg/L), TCE (4 µg/L), and vinyl chloride (1 µg/L). Carbon disulfide was also detected at 12 µg/L. Semivolatile organics, pesticides, and PCBs were not found at LE-01.

In the unfiltered sample, all of the major-metal ions (aluminum, iron, calcium, magnesium, sodium, and potassium) were detected. Aluminum and iron concentrations were 60,500 and 133,000 µg/L. Basic cations ranged from 3,620 to 14,900 µg/L. Barium, beryllium (328 and 11.2 µg/L, respectively), and eight heavy metals were detected. Concentrations ranged from 3.7 to 49.8 µg/L for beryllium, arsenic, chromium, copper, nickel, and vanadium. For lead, manganese, and zinc, concentrations ranged from 150 to 814 µg/L. In the filtered samples, all major-metal ions except for aluminum were detected, as were barium and manganese. All of these metals, with the exception of arsenic, were found in groundwater from the shallow overburden background well. In comparison, concentrations were as much as three times greater for barium and beryllium, five times greater for aluminum, 10 times greater for iron, and 30 times greater for lead.

Ammonia, sulfide, cyanide, and BOD were not detected. Total organic content was measured at 8.4 mg/L. A conductivity of 100 µmhos/cm and a pH of 5.4 were measured.

Summary of Leachate Findings. As indicated by subsurface soil and landfill gas data, the Bulky Waste and Solid Waste Areas still serve as a viable source of organic compounds and metals. The same types of chlorinated and aromatic volatile organics were found at relatively low concentrations in leachate as in other media in the vicinity of the disposal areas. The leachate seeps were also characterized by large amounts of orange floc and stained ground cover, which is indicative of metals (i.e., iron), precipitating/coagulating such as iron hydroxide under oxidizing conditions. Concentrations of several metals, including barium, lead, manganese, and iron, were found to be significantly elevated in leachate in comparison to levels in the shallow overburden groundwater at the background well. This is important since surface water bodies (Mitchell Brook and Saugatucket River) are within a few feet of the seeps.

F. Landfill Gas

Landfill gas samples were collected from each of the disposal areas and from permanent off-site monitoring points in June and July 1991 as part of the Site reconnaissance activities. The off-site monitoring points were again measured in September 1991. Percent carbon dioxide (CO_2), methane (CH_4), oxygen (O_2), and percent of the lower explosive limit (LEL) were measured, and nearly all of the points were analyzed using a field GC equipped with a PID.

In December 1991, additional points were sampled offsite to define the areal extent of landfill gas migration and its proximity to adjacent residences. At this time, 16 additional permanent monitoring points were installed. Eight were located near homes, and eight were located along the furthest known extent of the landfill gas plume (Figure 23). Each of the eight points near adjacent homes and selected other permanent points were monitored monthly from January through April 1992. Approximately 24 of the 48 permanent points were measured during each of these monthly sampling rounds.

In May 1992, six points were sampled using SUMMA passivated canisters for laboratory analysis of volatile organics by method TO-14 (Figure 24). At the same time, impingers were used to collect and analyze samples for reduced sulfur, consisting of hydrogen sulfide and mercaptan sulfur in the landfill gas, using ASTM method D 2385-81. The impingers were analyzed in an on-site laboratory. Samples from these locations were also analyzed using the field GC. A detailed discussion of analytical methodologies, sample collection procedures, and data use is presented in section 2.5.8 of the RI report.

Sewage Sludge Area. Twenty-two points were sampled in the sewage sludge area in June 1991. These points were located using a 100-foot-by-100-foot grid and are shown on Figure 25. Many of the grid points were omitted because volatile organics were not detected in adjacent samples and concentrations of methane and carbon dioxide were much lower than in the other disposal areas. One point [SS(08+000)] was resampled in May 1992 for SUMMA canister and reduced sulfur analysis, as shown on Figure 26.

Carbon dioxide was the primary component of landfill gas throughout the Sewage Sludge Area. Methane was detected at one point SS(08+000) at a concentration above the LEL. The concentrations of these compounds, as discussed in the following sections, were much lower than were detected in other disposal areas. Carbon dioxide and methane in landfill gas result from the biological degradation of organic materials placed into a landfill. Digested sewage sludge disposed of in this area was previously degraded during primary and secondary treatment. This material would not be expected to consume as much oxygen or produce as much methane or carbon dioxide as untreated municipal waste.

The only volatile organic detected above the quantitation limit in either the field GC or the SUMMA canister analysis was acetone at SS(08+000). Volatile organic data for soil (sections 4.2.1 and 4.2.2 of the RI) from this area are consistent with this finding. Acetone was detected at two of the surface soil locations (SS-11 and SS-12) and in three of the subsurface soils (BH-01 from 4 to 6 feet and 8 to 10 feet; BH-03 from 18 to 20 feet). 2-Butanone was also detected in all of these samples except SS-11. Toluene was detected in one of the soil samples (BH-03 from 18 to 20-feet), and TCE was detected at a concentration below its sample quantitation limit in SS-11.

In addition to acetone, several other volatile organics (methylene chloride, ethylbenzene, *m,p*-xylene, *o*-xylene, 1,3,5-trimethylbenzene, and 1,2,4-trimethylbenzene) were detected in the SUMMA canister sample at concentrations below the sample quantitation limit.

Bulky Waste Area. Twenty-nine points, shown on Figure 25, were sampled in the Bulky Waste Area in July 1991. These were located using a 100-foot-by-100-foot grid. Many of the grid points were omitted because the landfill gas was found to contain similar concentrations of the same compounds from point to point. Two points [BW(04+100) and BW(05+500)] were resampled in May 1992 for volatile organics using a SUMMA canister and also for reduced sulfur analysis, as shown on Figure 26.

Carbon dioxide and methane concentrations were greater than 25% throughout most of the Bulky Waste Area and were measured as high as 49% for carbon dioxide and 57% for methane. Oxygen concentrations were generally depressed from ambient air concentrations to as low as 1%.

Volatile organics were present throughout the disposal area but had elevated concentrations at some hot spots such as BW(05+400), BW(05+500), BW(04+100) and BW(01+300). The relative concentrations of different volatile organic compounds in the landfill gas also varies. Toluene, *cis*-1,2-DCE, and TCE were the primary compounds detected during the field GC analysis.

Toluene had the highest concentration of any component identified during the analysis of SUMMA canister samples collected from BW(04+100) and BW(05+500). Other aromatic compounds were also detected in each of these samples.

Chlorinated compounds were present in greater quantities in BW(04+100) than in BW(05+500). Vinyl chloride and *cis*-1,2-DCE had the highest concentrations of the chlorinated compounds in BW(04+100). The compounds 1,1-DCA, chloroethane, *trans*-1,2-DCE, 1,1,1-TCA, methylene chloride, PCE and TCE were also detected.

In BW(04+100), the ketone MEK was detected in both of the SUMMA samples, while acetone was the only ketone detected.

Dichlorodifluoromethane was detected at a higher concentration in BW(05+500) than in BW(04+100). Trichlorofluoromethane was detected in both samples, while Freon 113 was only detected in BW(04+100).

Hydrogen sulfide was detected at both BW(04+100) and BW(05+500), while mercaptans were not detected at either point.

Solid Waste Area. Eighty-five points were sampled in the Solid Waste Area in June and July 1991. These points were located using a 100-foot-by-100-foot grid. The actual sampling locations are shown on Figure 25. Three points [SW(03+300), SW(11+500) and SW(13+300)] were resampled in May 1992 for SUMMA canister and reduced sulfur analysis, as shown on Figure 26. Permeation of the landfill gas through the cover material of the Solid Waste Area was measured using two flux boxes installed in February 1992.

Carbon dioxide and methane concentration were greater than 35% throughout most of the Solid Waste Area and ranged as high as 62% for carbon dioxide and 60% for methane. Oxygen concentrations were generally depressed from ambient air concentration to as low as 1%.

Volatile organics were present throughout the disposal area but appear to have elevated concentrations at SW(11+500) and SW(13+200). The relative concentrations of different volatile organic compounds in the landfill gas also appear to vary. Toluene, *cis*-1,2-DCE, and TCE were the primary compounds detected during the field GC analysis. For the SUMMA canister data, *cis*-1,2-DCE had the highest concentration of any volatile organic in the Solid Waste Area. Vinyl chloride had the second highest concentration at SW(13+300) and SW(11+500). Chloromethane, chloroethane, 1,1-DCE, methylene chloride, *trans*-1,2-DCE, 1,1-DCA, 1,1,1-TCA, TCE, and PCE were all detected at these two points.

At SW(03+300), aromatic compounds were the primary volatile organics present in the SUMMA canisters. Although most of the same chlorinated compounds are present, the concentrations of toluene, ethylbenzene, *p*-xylene, and *o*-xylene are higher than those of any of the chlorinated compounds.

Of the Freon compounds, dichlorofluoromethane was present in all of the Solid Waste Area SUMMA canisters. Freon 114 and 113 and trichlorofluoromethane were present periodically.

2-Butanone was the only ketone detected, and it was present at a much lower concentration relative to other volatile organics.

Carbon disulfide was present in two of the four samples, and bromoform was found in only one of the four samples from the Solid Waste Area. These compounds were present at concentrations much less than those of other volatile compounds detected in these samples.

Reduced sulfur analysis indicated hydrogen sulfide results ranging from 1.0 to 6.3 mg/m^3. No mercaptan sulfur was detected.

Of the two flux boxes installed on the Solid Waste Area, FLUXEAST indicates that landfill gas is readily passing through the landfill cover material. Concentrations of methane, carbon dioxide, and volatile organic compounds appeared similar to concentrations of these compounds in landfill gas detected in the same area.

Delineation of Off-Site Landfill Gas Plume. In June and July 1991, 32 permanent landfill gas sampling points were installed around the perimeter of the Solid Waste Area. Nine points, spaced at approximately 100-foot intervals, were placed at the north end of the Solid Waste Area along the driveway at the northern boundary. Eighteen points were placed along the west side of Rose Hill Road also at approximately 100-foot intervals. Five points were placed at the southern perimeter of the Solid Waste Area, just inside the fence that divides the Solid Waste Area from the transfer station road, again at approximately 100-foot intervals.

These sampling points are shown on Figure 27. Permanent sampling points along the driveway north of this disposal area are designated LFGF. Permanent sampling points west of the Solid Waste Area along Rose Hill Road are designated LFGR. Points south of the Solid Waste Area along the transfer station road are designated LFGT.

Sampling of the perimeter landfill gas monitoring points in July and September 1991 indicated that landfill gas was migrating from the Solid Waste Area to the north, west, and south. Elevated methane, carbon dioxide, and total volatile organics were identified at LFGF-03 to the north of the Site. *cis*-1,2-dichloroethene and vinyl chloride were the primary volatile components identified at this point. TCE, toluene, ethylbenzene, and xylenes were also identified.

The largest area of landfill gas migration was along the western perimeter of the Site. The highest landfill gas concentrations were at LFGR-08. Methane and carbon dioxide concentrations at this point were consistently high. *cis*-1,2-dichloroethene and vinyl chloride were the primary volatile components identified at this point. Trichloroethene, toluene, ethylbenzene, and xylenes were also identified. Although LFGR-08 had the highest concentrations of off-site landfill gas, this plume appeared to extend from LFGR-07 as far south as LFGR-14. Although the landfill gas plume leaving the western perimeter of the Solid Waste Area was about 700 feet wide, it appeared to extend only about 200 feet west from the landfill.

South of the Solid Waste Area, methane, carbon dioxide, and volatiles were found to migrate south of the transfer station road. This plume extended the width of the southern end of the Solid Waste Area and approximately 100 feet south of the transfer station road. The volatile organic compounds detected south of the solid waste area varied from those detected to the north and west. The high concentrations of *cis*-1,2-DCE and vinyl chloride exhibited in the landfill gas north and west of the Solid Waste Area were not present south of the disposal area.

Volatile organics were detected at three permanent residential sampling locations (LFG-LHR, LFG-GT, and LFG-AD). Methane was detected at only one of these (LFG-LHR).

G. Contaminant Fate and Transport

Predominant transport processes for contaminants identified at the Site are leachate runoff, landfill gas migration, groundwater flow through overburden and bedrock, and surface water and sediment movement. Landfill gas migration, groundwater, and leachate are the primary contaminant transport mechanisms in the unsaturated zone. Venting of landfill gas was evident where soil/fill cover material was thin or absent; however, movement of gas into surface soil may decrease volatilization to the atmosphere. In areas of high landfill gas contamination, groundwater quality was affected.

Highest contaminant concentrations in groundwater were found in wells adjacent to the disposal areas and decreased with distance from these areas. The predominant groundwater flow direction is south-southeast in the overburden and southeast in the bedrock, although mounding effects in the northwest portion of the Solid Waste Area facilitate radial migration of contaminants towards the west, north, and northeast. Mitchell Brook intercepts contamination in the shallow and deep overburden, while the Saugatucket River is a receptor for shallow and deep overburden and bedrock contamination. Glacial lacustrine deposits restrict the vertical movement of contaminants from deep to shallow overburden in the southern portion of the Site. Bedrock fractures provide pathways for contaminant transport in groundwater from overburden to bedrock.

Transport of contaminants via leachate has impacted surface soil, surface water, and sediment quality near the disposal areas. However, downgradient in the Saugatucket River, surface water and sediment contamination decreased. Likewise, in Mitchell Brook, contamination increased south of the Solid Waste Area but decreased after the confluence with the Saugatucket River. This trend indicates dilution of contaminated surface water by uncontaminated surface water and/or sediment retention of contamination.

VI CURRENT AND FUTURE SITE AND RESOURCE USES

A. Current Land Use

Current land use is varied within the Site. The landfills are and will remain inactive. The Solid Waste Area landfill is posted and partially fenced along Rose Hill Road and the transfer station road to restrict access. The properties within the Site boundary include residential and commercial uses. North and east of the Sewage Sludge Area, the Site owner conducts his business of sport, target and archery ranges, dog training, birding and exercising. A kennel is located on the northern portion of the Site, west of the Sewage Sludge Area. Sporting ranges are located north and east of the kennel. An active Town-operated regional transfer station and recycling center reside on the southeast corner of the Site. Saugatucket and Broadrock Roads, and a portion of Rose Hill Road (south and up to the Site), are serviced with public water; connections to the waterline were voluntary. Some residents located west and north of the Site along Rose Hill Road and along Broadrock Road are not connected to public water and use private wells. New housing developments, all of which are connected to municipal water, have been constructed southwest of the Site, on the west side of Rose Hill Road, northeast of the Site, across the River on Broadrock Road and southwest of the Site along Saugatucket Road. Across from the landfill on Rose Hill Road, small commercial excavation businesses and sand and gravel operations are conducted. A family-owned farm is located west-northwest of the Site, along Rose Hill Road.

B. Future Land Use

The Town of South Kingstown has indicated an interest in expanding the recycling operations in the vicinity of the transfer station. The Site owner has also shown interest in maintaining sporting and kennel operations within the Site boundary. The Town informed EPA and the State that it has had discussions with the Site owner's family members and abutters concerning certain real property acquisitions; however, EPA has not been involved in these discussions.

A 29- unit housing development (known as South Woods) is proposed north of the Site and south of Rte 138; this development will be connected to municipal water. Further, there are discussions among certain residents on Rose Hill Road and a local developer of a future proposal for a golf course within the footprint of the existing sand and gravel operations on Rose Hill Road.

Consolidation of the wastes from the Bulky Waste Area landfill onto the Solid Waste Area landfill may allow for more future, albeit restricted, uses on portions of the Site. Based on current zoning, it is reasonable to expect that the future land use will be similar to that which is currently in the immediate vicinity of the Site (i.e. rural residential with intespersed commercial real estate along Rose Hill Road and rural residential along Broadrock and Saugatucket Road.

C. Current and Future Surface Water Use

The River in the vicinity of the Site is classified by the State as a Class B waterway meaning that the River is not of drinking water quality but is presumed to have a good aesthetic, recreational, and ecological value. As documented in the RI/FS and the Preliminary Natural Resource Survey (PNRS), leachate production and groundwater flow from the landfill result in impacts to aquatic life and water quality in the Saugatucket River, Mitchell Brook (and, according to the PNRS, to the Saugatucket Pond). These waters are listed for biodiversity impacts on the State's 1998 list of impaired waters. Under Section 303 of the Federal Clean Water Act, the State is required to develop a total Maximum Daily Load (TMDL) program for bringing impaired waters into compliance with state water quality standards and supporting all designated uses. Rhode Island has stated that development of TMDLs for the aforementioned waterbodies will begin in the year 2000. The selected remedy will be consistent with the State's TMDL's goals.

The Saugatucket River Heritage Corridor Coalition has adapted a goal of maintaining swimmable/fishable water quality conditions in the watershed. Regionally, plans are being drawn to develop a protective greenway and bike trail to follow portions of the Saugatucket River in Wakefield and surrounding communities.

D. Current and Future Groundwater Use

Rhode Island does not have an EPA-endorsed Comprehensive State Ground Water Protection Program (CSGWPP) – EPA's process for groundwater decisionmaking by states. Therefore, Superfund guidance requires EPA to follow the NCP for federal groundwater classification in states without a CSGWPP and to coordinate with the States during remediation activities. The federal classification for this Site groundwater is Class II-B, defined as a potential drinking water source and water having other beneficial uses. Local area groundwater surrounding the Site is classified as Class II-A which is defined as a current drinking water source and water having other beneficial uses.[1]

Although Rhode Island does not have an endorsed CSGWPP, RIDEM did submit correspondence in December 1996 setting forth its opinion on the use and value of groundwater aquifer underlying the Site as medium use (designates a flexible approach to groundwater remediation). Ultimately, all of the aquifer, except that underlying the footprint of the disposal area, would be restored to GA (suitable for public or private drinking water use without treatment); the aquifer under the disposal area would be restored to GB (degraded–not suitable for public or private drinking water). The State also noted some small GA-NA (non-attainment areas with pollutant concentrations greater than those suitable for public or private drinking water without treatment). Restoration for GA-NA areas is to drinking water standards with some flexibility on time for attaining those standards.

EPA believes that its remediation plans for this Site are consistent with both the federal and state classifications for use and value of the groundwater aquifer. Source control measures will prevent further migration of contaminant into the groundwater as well as prevent further leachate from entering the groundwater and surface water. Excavation and consolidation of the Bulky Waste Area, a portion of which currently sits in the groundwater table, also eliminates a significant source of contamination to groundwater. It is also possible that capping will, over time, eliminate any possible mounding effects of groundwater in the Solid Waste Disposal area. Once the source control remedy has been implemented, additional data produced during long-term monitoring will indicate whether or not further response actions are necessary to bring groundwater to appropriate use and value standards.

VII. SUMMARY OF SITE RISKS

A baseline risk assessment was performed to estimate the probability and magnitude of potential adverse human health and environmental effects from exposure to contaminants associated with the Site assuming no remedial action was taken. It provides the basis for taking action and identifies the contaminants and exposure pathways that need to be addressed by the remedial

---

[1]Groundwater Use and Value Determination Guidance, EPA Region1-New England, (April 3, 1996); EPA Office of Solid Waste and Emergency Response (OSWER) Dir. 9283.1-09, April 4, 1997; EPA's Groundwater Protection Strategy (Office of Groundwater Protection, August 1984); and Guidelines for Groundwater Classification under the EPA Groundwater Protection Strategy (Final Draft, Office of Groundwater Protection, November 1986).

action. The public health risk assessment followed a four step process: 1) contaminant identification, which identified those hazardous substances which, given the specifics of the Site were of significant concern; 2) exposure assessment, which identified actual or potential exposure pathways, characterized the potentially exposed populations, and determined the extent of possible exposure; 3) toxicity assessment, which considered the types and magnitude of adverse health effects associated with exposure to hazardous substances, and 4) risk characterization, which integrated the three earlier steps to summarize the potential and actual risks posed by hazardous substances at the Site, including carcinogenic and non-carcinogenic risks. A summary of those aspects of the human health risk assessment which support the need for remedial action is discussed below followed by a summary of the environmental risk assessment.

A. Human Health Risk Assessment

Only groundwater, at the three landfill areas and at nearby residences, and air, at the Solid Waste Area (i.e., landfill gas) and nearby residences, present a Reasonable Maximum Exposure (RME) cancer risk greater than 10-4 or an HI >1. Forty-three contaminants of concern (listed in Tables 27 through 34 for groundwater, and Tables 35, 36, 37 through 42, 43, and 44 for air) of more than 50 contaminants detected at the Site were selected for evaluation in the human health risk assessment. The contaminants of concern for groundwater and for air from the Final Supplemental Human Health Risk Assessment (November 1998) were selected to represent potential Site related hazards based on toxicity, concentration, frequency of detection, and mobility and persistence in the environment. They represent a subset of all the compounds evaluated in the baseline risk assessment. Tables 28, 30, 32, and 34 for ground water, and 36, 38, 40, and 44 for air, from the Final Supplemental Human Health Risk Assessment also contain the exposure point concentrations used to evaluate the RME in the baseline risk assessment. Estimates of average or central tendency exposure concentrations can be found in the Final Supplemental Human Health Risk Assessment. Tables 45 and 46 from the Final Supplemental Human Health Risk Assessment and Table 47 (for air) as well as Tables 48 through 50 and 51 (for groundwater) from the Final RI Report (May 1994) provide a summary of the range of detected concentrations and frequency of detection for the compounds of concern in both media.

Potential human health effects associated with exposure to the contaminants of concern were estimated quantitatively or qualitatively through the development of several hypothetical exposure pathways. These pathways were developed to reflect the potential for exposure to hazardous substances based on the present uses, potential future uses, and location of the Site. The following is a brief summary of just the exposure pathways that were found to present a significant risk. A more thorough description of all exposure pathways evaluated in the risk assessment including estimates for an average exposure scenario, can be found in Section 7.0 of the Final Supplemental Human Health Risk Assessment, November, 1998.

For the inhalation of contaminated ambient and indoor air, both measured and modeled concentrations were evaluated. For modeling, measured landfill gas concentrations were used and adjusted using emission and dispersion modeling. Exposures to ambient air at the Solid Waste Area surface were assumed to occur for an adult Site visitor 4 hr/day, 150 days/year, for 30 years. At the nearby residences, adult inhalation exposures were assumed to occur 24 hr/day, 350 days/year, for 30 years.

Excess lifetime cancer risks were determined for each exposure pathway by multiplying a daily intake level with the chemical specific cancer potency factor. Cancer potency factors have been developed by EPA from epidemiological or animal studies to reflect a conservative "upper bound" of the risk posed by potentially carcinogenic compounds. That is, the true risk is unlikely to be greater than the risk predicted. The resulting risk estimates are expressed in scientific notation as a probability (e.g. 1×10^{-6} for 1/1,000,000) and indicate (using this example), that an average individual is not likely to have greater that a one in a million chance of developing cancer over 70 years as a result of site-related exposure (as defined) to the compound at the stated concentration. All risks estimated represent an "excess lifetime cancer risk" or the additional cancer risk on top of that which we all face from other causes such as cigarette smoke or exposure to ultraviolet radiation from the sun. The chance of an individual developing cancer from all other (non-site related) causes has been estimated to be as high as one in three. EPA's generally acceptable risk range for site related exposure is 10^{-4} to 10^{-6}. Current EPA practice considers carcinogenic risks to be additive when assessing exposure to a mixture of hazardous substances.

In assessing the potential for adverse effects other than cancer, a hazard quotient (HQ) is calculated by dividing the daily intake level by the reference dose (RfD) or other suitable benchmark. Reference doses have been developed by EPA and they represent a level to which an individual may be exposed that is not expected to result in any deleterious effect. RfDs are derived from epidemiological or animal studies and incorporate uncertainty factors to help ensure that adverse health effects will not occur. A HQ<1 indicates that a receptor's dose of a single contaminant is less than the RfD, and that toxic noncarcinogenic effects from that chemical are unlikely. The Hazard Index (HI) is generated by adding the HQs for all chemical(s) of concern that affect the same target organ (e.g. liver) within or across all media to which a given individual may reasonably be exposed. A HI <1 indicates that toxic noncarcinogenic effects are unlikely.

The scope of the first operable unit response for this Site is a source control action as part of a phased clean up approach. Groundwater and the risks posed by contaminants in groundwater will be further assessed using monitoring data collected during the implementation of the first operable unit and any additional studies deemed necessary and addressed under a second operable unit response action. However, based on the findings of the RI, EPA acknowledges that the cumulative excess RME cancer risk posed by present and potential future ingestion of groundwater as a drinking water source is outside of EPA's acceptable risk range for Site related exposures. Tables 52 through 55 depict the carcinogenic and non-carcinogenic risk summary for the contaminants of concern in groundwater evaluated to reflect present and potential future adult residential ingestion of Site groundwater as drinking water corresponding to the reasonable maximum exposure (RME) scenario. As such, the risk posed by this exposure route justifies the use of institutional controls as part of the remedy for this first operable unit response.

Tables 56 through 60 depict the carcinogenic and non-carcinogenic risk summary for the contaminants of concern in air evaluated to reflect present and potential future inhalation of ambient air by Solid Waste Area visitors and ambient/indoor air by area residents corresponding to the reasonable maximum exposure (RME) scenario. Only those exposure pathways deemed relevant to the remedy being proposed are presented in this ROD. In addition, only those compounds contributing an RME cancer risk in excess of 10^{-6} or an HQ>1 have been presented. Readers are referred to Section 7.0 of the Final Supplemental Human Health Risk Assessment for a more comprehensive risk summary of all exposure pathways and for estimates of the central tendency risk. Toxicity information used for the risk calculations can be found in Tables 61 and 62 of the Final Supplemental Human Health Risk Assessment.

For the air pathway, benzene, 1,1-dichloroethene, 1,1,2,2-tetrachloroethane, and vinyl chloride contribute significantly to carcinogenic and non-carcinogenic risk. The cumulative excess RME cancer risks posed by the inhalation of measured outdoor air concentrations at the Solid Waste Area and measured ambient air concentrations at the nearby residences are 4.4×10^{-4} and 5×10^{-4}, respectively. Using modeled concentrations, the cumulative excess RME cancer risks posed by the inhalation of ambient air at the Solid Waste Area and ambient/indoor air at the nearby residences are 4.4×10^{-4} and 4.6×10^{-4}, respectively. Using measured indoor air concentrations at 220 Rose Hill Road, the cumulative excess RME cancer risk posed by the inhalation of air is 1.9×10^{-3}. The non-carcinogenic hazards posed by the inhalation of measured and modeled ambient air concentrations at the nearby residences are both 12 times the EPA safe level indicating that adverse blood effects are possible as a result of chronic exposure to benzene.

Limitations and uncertainties in the risk assessment include adequacy of site characterization and sampling, quality of analytical data, accuracy of exposure assumptions, use of modeling to develop EPCs, and development of toxicity values. Most important for this risk assessment, conservative exposure assumptions were used for exposure concentrations (i.e., maximum detected concentrations) and for frequency and duration of exposure. These conservative assumptions can potentially result in an overestimate of risk to human receptors. In addition, exposure point concentrations derived by modeling have considerable uncertainty since the modeled concentrations are based on: (1) limited sampling; (2) predicted, rather than measured landfill gas generation rates; and (3) conservative assumptions for specific input parameters. Each of these uncertainties may result in an over-, or under- estimate of receptor risk.

Further detail concerning the Human Health Risk Assessment can be found in Section 3.6 of the Administrative Record.

Click here to go to Part 3 of Decision Summary